Introduction

What is the condition of Earth's many surface waters – the streams, rivers, lakes, and coastal waters? How do these conditions vary over the year? Are these conditions changing from year to year?

Through the GLOBE *Hydrology Investigation*, you can help address these questions by monitoring the waters near your school. Our knowledge of global trends in water measurements is based on sampling at very few sites. This sampling has generally been done only a few times. For example, our information on many lakes is based on sampling done only once or twice more than ten years ago.

In order to evaluate water changes, we need access to reliable information on current and past conditions. If changes are already taking place, comparing multiple sites at different areas can help us understand what is happening.

Why Investigate the Surface Waters?

We do not just drink water; we are water. Water constitutes 50 to 90 percent of the weight of all living organisms. It is one of the most abundant and important substances on Earth. Water sustains plant and animal life, plays a key role in the formation of weather, helps to shape the surface of the planet through erosion and other processes, and approximately 70% of Earth's surface is covered in water.

Measures of dissolved oxygen and pH directly indicate how hospitable a body of water is to aquatic life. It is interesting to both follow the annual cycle of water parameters, such as dissolved oxygen, alkalinity and pH, and to make comparisons between different water bodies. We can ask such questions as: are dissolved oxygen levels always at the maximum allowed by the temperature of the water, or are they depressed during part of the year? If they are low, we want to know the cause. We can see if pH becomes depressed right after a rain or when there is a lot of snowmelt running off into the lake or stream. If we do find a depression in pH, we would expect this water to have a low level of alkalinity. In fact, we would expect waters with a low alkalinity to have a depression in pH following rainfall or snowmelt. But we must take the measurement to confirm whether or not this really happens. Developing a database of water measurements will allow us to answer such questions.

Despite its abundance, we cannot use most of Earth's water. If we represent Earth's water as 100 liters, 97 of them would be seawater. Most of the remaining three would be ice. Only about 3 mL out of the whole 100 liters would be fresh water that we can consume; this potable water is pumped from the ground or taken from fresh water rivers and lakes.

In most countries current measurement programs cover only a few water bodies a few times during the year. We hope the GLOBE measurements you take will help fill this gap and improve our understanding of Earth's natural waters. This knowledge can help us make more intelligent decisions about how we use, manage and enjoy these resources.

The Big Picture

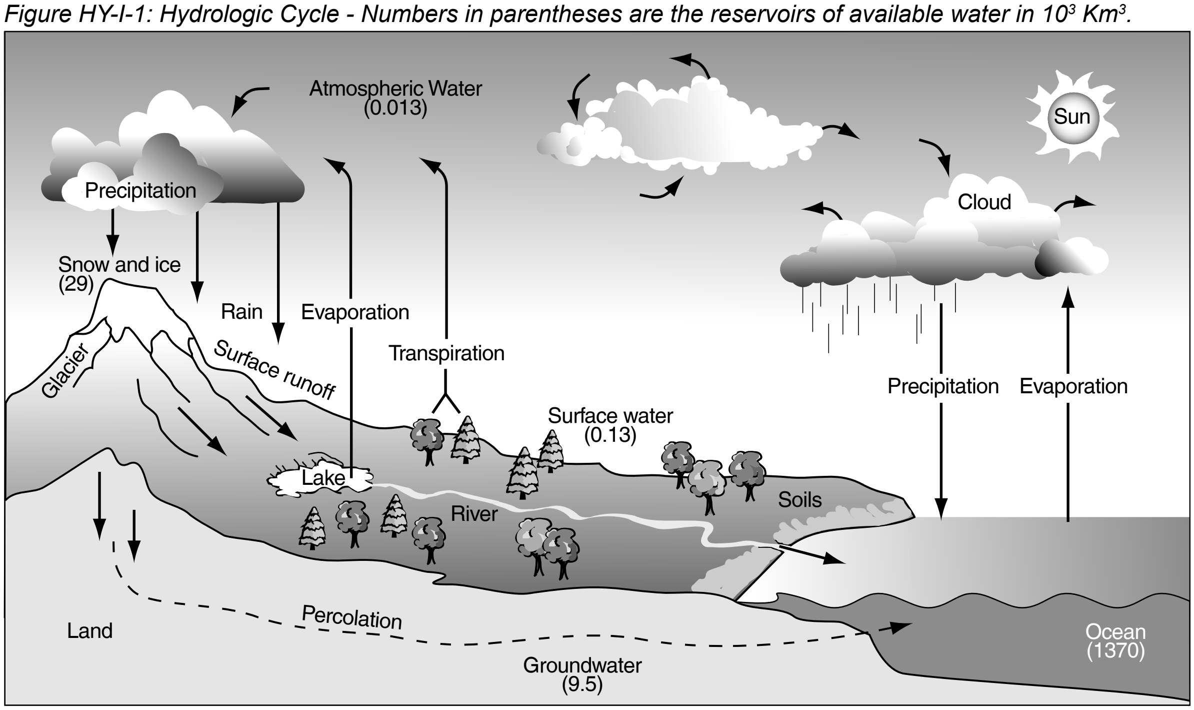
The Hydrologic Cycle

Water continually circulates between Earth's surface and atmosphere in what is called the hydrologic cycle. The hydrologic, or water, cycle is one of the basic processes in nature. Responding to heat from the sun and other influences, water from oceans, rivers, lakes, soils and vegetation evaporates into the air and becomes water vapor. Water vapor rises into the atmosphere, cools, and turns into liquid water or ice to become clouds. When water droplets or ice crystals get large enough, they fall back to the surface as rain or snow. Once on the ground water filters into the soil and is either absorbed by plants or percolates downward to groundwater reservoirs. If water does not filter into the soil, it runs off into streams and rivers and eventually into oceans, while some of it evaporates.

Waters in a lake, snow on a mountain, humid air or drops of morning dew are all part of the same system. Total annual water loss from the surface equals Earth's total annual precipitation. Changing any part of the system, such as the amount of vegetation in a region or land cover, affects the rest of the system.

Water participates in many important chemical reactions and is a good solvent. Completely pure water rarely occurs in nature because it carries impurities as it travels through the hydrologic cycle. Rain and snow capture aerosols from the air. Acidic water slowly dissolves rocks, placing dissolved solids in water. Small but visible pieces of rocks and soils also can become suspended in water and make some waters turbid. When water percolates into the ground, more minerals dissolve into water. Dissolved or suspended impurities determine water's chemical composition.

Figure HY-I-1: Hydrologic Cycle - Numbers in parentheses are the reservoirs of available water in 10^3 Km^3.



After Mackenzie and Mackenzie 1995, and Graedel and Crutzen, 1993

GLOBE Measurements

What Measurements are Taken?

In this investigation students will measure the following water measurements:

- Transparency
- Water Temperature
- Dissolved Oxygen
- Electrical Conductivity
- Salinity
- pH
- Alkalinity
- Nitrate
- Optional (Protocols on the GLOBE e-Guide):
  - Salinity Titration
  - Freshwater Macroinvertebrates

Individual Measurements

Transparency

Light, essential for growth of green plants, travels farther in clear water than in turbid water that contains suspended solids or colored water. Transparency is the degree to which light penetrates into water. Two methods commonly used to measure transparency are the Secchi disk and transparency tube. The Secchi disk was first used to measure transparency in 1865 by Father Pietro Angelo Secchi, the scientific advisor to the Pope. This simple and widely used measurement is the depth at which a 20-cm black and white disk lowered into water just disappears from view, and reappears again when raised. An alternate measure of transparency is obtained by pouring water into a tube with a pattern similar to that of a Secchi disk on the bottom and noting the depth of water in the tube when the pattern just disappears from view. The Secchi disk is used in deeper, still waters. The transparency tube can be used with either still or flowing waters and can be used to measure shallow water sites or the surface layer of deepwater sites.

Water Temperature

Water temperature is largely determined by the amount of solar energy absorbed by the water as well as the surrounding soil and air. More solar heating leads to higher water temperatures. Water used in manufacturing and then discharged into a water body may also increase water temperature. Water evaporating from the surface of a water body can lower the temperature of water but only for a very thin layer at the surface.

Water temperature can be indicative of where the water originates. Water temperature near the source will be similar to the temperature of the source (e.g., snowmelt will be cool whereas some ground water is warm). Water temperature farther from the source is influenced largely by atmospheric temperature.

Other parameters, such as electrical conductivity and dissolved oxygen, are dependent on water temperature. It is also an important factor for what will live in a water body.

Dissolved Oxygen

Water is a molecule made of two hydrogen atoms and one oxygen atom – hence, H_2O. However, mixed in with the water molecules of any body of water are molecules of oxygen gas (O_2) that have dissolved in the water. Dissolved oxygen is a natural impurity in water. Aquatic animals, such as fish and the zooplankton they feed on, do not breathe the oxygen atom in water molecules. Rather, they breathe the oxygen molecules dissolved in the water. Without sufficient levels of dissolved oxygen in the water, aquatic life suffocates. Dissolved oxygen levels below 3 mg/L are stressful to most aquatic organisms.

pH

pH is a measure of the acid content of water. The pH of a water influences most of its chemical processes. Pure water with no impurities (and not in contact with air) has a pH of 7. Water with impurities will have a pH of 7 when its acid and base content are exactly equal and balance each other out. At pH values below 7 there is excess acid, and at pH levels above 7 there is excess base in the water.

Electrical Conductivity

Pure water is a poor conductor of electricity. It is the ionic (charged) impurities in water, such as dissolved salts, that enable water to conduct electricity. Since we lack the time or money to analyze water for each substance, we have found a good indicator of the total level of impurities in fresh water to be its electrical conductivity. Electrical conductivity is the measurement of how well water passes an electrical current. The more dissolved salts there are in water, the greater its electrical conductivity.

Salinity

Water in seas and oceans is salty and has a much higher dissolved solids content than in freshwater lakes, streams and ponds. Salinity is a measure of that saltiness and is expressed in parts impurity per thousand parts water. The average salinity of Earth's oceans is 35 parts per thousand (35 ppt). Sodium and chloride, the components of common table salt (NaCl), contribute most to the salinity. In bays and estuaries we can find a wide range of salinity values since these are the regions where freshwaters and seawater mix. The salinity of these brackish waters is between that of freshwater, which averages 0.5 ppt, and seawater.

Every continent on Earth also has inland lakes that are saline. Some of the more prominent examples are the Caspian Sea in Central Asia, the Great Salt Lake in North America, and several lakes in the Great Rift Valley of East Africa. Some of these are even more saline than seawater. Waters acquire salinity because rivers carry salts that originated from the weathering or dissolving of continental rocks. When water evaporates the salts stay behind, resulting in a buildup of dissolved material. When water becomes saturated with salts, they precipitate out as solids. Whereas the ocean's salinity changes slowly, over many millennia, the salinity of inland waters can change more quickly, over hours to decades, when rainfall or snowmelt patterns change.

Alkalinity

Alkalinity is the measure of a water's resistance to the lowering of pH when acids are added to the water. Acid additions generally come from rain or snow, though soil sources are also important in some areas. Alkalinity is generated as water dissolves rocks containing calcium carbonate such as calcite and limestone. When a lake or stream has low alkalinity, typically below about 100 mg/L as $CaCO_3$, a large influx of acids from a big rainfall or rapid snowmelt event could (at least temporarily) drop the pH of the water to levels harmful for amphibians, fish or zooplankton.

Nitrate

Plants in both fresh and saline waters require three major nutrients for growth: carbon, nitrogen and phosphorus. In fact, most plants tend to use these three nutrients in the same proportion, and cannot grow if one is in short supply. Carbon is relatively abundant in the air as carbon dioxide. Carbon dioxide dissolves in water and so a lack of either nitrogen or phosphorus generally limits the growth of aquatic plants. In some cases, trace nutrients such as iron can also be limiting. Sunlight can also limit growth. Nitrogen exists in water bodies in numerous forms: dissolved molecular nitrogen (N_2), organic compounds, ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Of these, nitrate is usually the most important for plant growth.

Freshwater Macroinvertebrates

Millions of small creatures inhabit fresh waters of lakes, streams, and wetlands. Macroinvertebrates, consisting of a variety of insects and insect larvae, crustaceans, mollusks, worms, and other small, spineless animals live in the mud, sand, or gravel of the substrate or on submersed plants and logs. They play a crucial role in the ecosystem. They provide an essential link in the food chain and are the source of food for many larger animals. Macroinvertebrates, such as freshwater mussels, help to filter water. Other types are scavengers and feed on decaying matter in the water, while certain macroinvetebrates prey on smaller organisms .

Macroinvertebrates can tell us a lot about the conditions within a water body. Many macroinvertebrates are sensitive to changes in pH, dissolved oxygen, temperature, salinity, transparency, and other changes in their habitat. Habitat is a place that includes everything that an animal needs to live and grow.

Macroinvertebrate samples allow us to estimate biodiversity, examine the ecology of the water body and explore relationships among water chemistry measurements and organisms at your Hydrology Site.

Where are the measurements taken?

All hydrology measurements are taken at the Hydrology Study Site. This may be any surface water site that can be safely visited and monitored regularly from your school, although natural waters are preferred.

Sites may include (in order of preference):

1. stream or river
2. lake, reservoir, bay or ocean
3. pond
4. an irrigation ditch or other water body if one of the above is not accessible or available

When are the measurements taken?

Collect all water measurements at roughly the same time each day, on a weekly basis. If your sampling site freezes over in winter or runs dry, be sure to enter this information each week until you again have free-flowing surface water to measure.

Note: Certain times of the year provide more exciting measurements. When runoff from a spring snowmelt is occurring on a river, the increased flow and sediment will dramatically change water measurements. One or more times a year, lakes can 'turnover' and the waters in the lake totally mix. This can occur in spring after the ice melts. Turnover can cause surprising changes to your measurement results. Be observant of seasonal and monthly changes. Use the *Comments* section of the GLOBE data entry pages to record observations that may help others interpret your water data.

Collect freshwater macroinvertebrate data twice a year, once in Spring and again in late Summer or early Autumn before the first freeze. If your seasons alternate between wet and dry, choose a date in the second half of the wet season and one date in the dry season, six months from the first sampling if possible. If you have no marked cyclic changes, ask local experts to find out when you should sample to find the peak abundance and diversity of macroinvertebrates in the water. Sample at that time and sample again six months later.

How many students should be involved?

Measurements should be taken by groups of 2-3 students. Tasks within a group include collecting samples, processing samples, and recording data. It is very useful to have multiple groups testing for each parameter (for example, three groups measure dissolved oxygen). This allows more students to get involved and builds in some quality control. Groups of students conducting the same test should look at each other's results to determine if the data are similar. If there are different results for the same sample, students should check the procedures and redo the test to determine what caused the difference. Data quality control should be an important part of the science and the learning experience.

Table HY-I-1: Hydrology Measurement Levels and Approximate Time Required

Level	Measurements	Time (minutes)
Beginning	Transparency	10
	Temperature	10
	pH (paper)	10
	Conductivity	10
	Salinity	10
Intermediate or Advanced	Dissolved oxygen	20
	pH (meter)	10
	Alkalinity	15
	Nitrate	20
Optional	Salinity Titration	10
	Freshwater macro-invertebrates	3-6 hours

Welcome Introduction Protocols Learning Activities Appendix

How long does it take to do the measurements?

The amount of time for doing the measurements will depend on the distance to your water site, the skill level of the students, and how your group is organized. If each student group performs all of the measurements it will take more time than if smaller groups are responsible for different sets of measurements each week.

Getting Started

For the weekly water protocols, students will take samples of water from a selected body of water, process the samples to determine their composition, and analyze the data to better understand the water and its impact on the environment. Each year, students are requested to map and photograph their site. One of the major factors that limit use of data is poor documentation of sites.

For the *Freshwater Macroinvertebrate Protocol,* students will sample their water sites twice a year to determine the relative number and types of invertebrates. Students will compare these data with the water chemistry data, historic data, and other indices to understand the patterns and trends of the water they are studying.

Educational Objectives

Students participating in the activities presented in this chapter should gain inquiry abilities and understanding of a number of concepts. These abilities include the use of a variety of specific instruments and techniques to take measurements and analyze the resulting data along with general approaches to inquiry. The *Scientific Inquiry Abilities* listed in the gray box are based on the assumption that the teacher has completed the protocol including the *Looking At The Data* section. If this section is not used, not all of the Inquiry Abilities will be covered. The *Science Concepts* included are outlined in the United States National Science Education Standards as recommended by the US National Research Council and include those for Earth and Space Science and Physical Science. The *Geography Concepts* are taken from the National Geography Standards prepared by the National Education Standards Project. Additional *Enrichment Concepts* specific to the hydrology measurements have been included as well. The gray box at the beginning of each protocol or learning activity gives the key concepts and scientific inquiry abilities covered. The following tables provide a summary indicating which concepts and abilities are covered in which protocols or learning activities.

References

T.E. Graedel and P.J. Crutzen (1993) *Atmospheric Change: An Earth System Perspective*. W.H. Freeman and Company, New York

F.T. Mackenzie and J.A. Mackenzie (1995) *Our Changing Planet: An Introduction to Earth System Science and Global Environmental Change*. Prentice Hall, New Jersey.

National Science Education Standards	Protocols						
	Trans.	Temp.	Dis. Oxygen	pH	E. Cond.	Salinity	Sal. Titration
Earth and Space Sciences							
Properties of Earth Materials (K-4)							
Earth materials are solid rocks, soils, water and the atmosphere	■	■	■	■	■	■	■
Soils have properties of color, texture and composition; they support the growth of many kinds of plants							
Soils consist of weathered rocks and decomposed organic matter							
Changes in the Earth and Sky (K-4)							
The surface of the Earth changes (Erosion, weathering, etc.)							
Structure of the Earth System (5-8)							
Landforms are the result of destructive and constructive forces							
Soil consists of weathered rocks and decomposed organic matter							
Water circulates through the biosphere, lithosphere, atmosphere and hydrosphere (water cycle)							
Water is a solvent	■		■	■	■	■	■
Energy in the Earth System (9-12)							
The sun is the major source of energy at Earth's surface							
Solar insolation drives atmospheric and ocean circulation							
Geochemical Cycles (9-12)							
Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere)			■	■	■	■	■
Physical Sciences							
Properties of Materials (K-4)							
Objects have observable properties	■	■	■	■	■	■	■
Life Sciences							
The Characteristics of Organisms (K-4)							
Organisms have basic needs.							
Organisms can only survive in environments where their needs are met		■	■	■	■	■	■
Earth has many different environments that support different combinations of organisms		■	■	■	■	■	■
Organisms and their Environments (K-4)							
Organisms' functions relate to their environment							
Organisms change the environment in which they live	■		■	■			
Humans can change natural environments	■	■	■	■	■	■	■
Structure and Function of Living Systems (5-8)							
Ecosystems demonstrate the complementarily nature of structure and function							
Regulation and Behavior (5-8)							
All organisms must be able to obtain and use resources while living in a constantly changing environment	■	■	■	■	■	■	■

			Learning Activities					
Alkalinity	Fresh water macro-invertebrates	Nitrate	Water Walk	Model Watershed	Water Detective	pH Game	Practice Protocols	Model Balance
■		■						
	■		■	■				■
	■							
			■	■				
			■	■				■
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■		■	■	■	■	■	■	
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■	■	■	■				■	

National Science Education Standards	Protocols						
	Trans.	Temp.	Dis. Oxygen	pH	E. Cond.	Salinity	Sal. Titration
Populations and Ecosystems (5-8)							
All populations living together and the physical factors with which they interact constitute an ecosystem							
Populations of organisms can be categorized by the function they serve in the ecosystem							
Sunlight is the major source of energy for ecosystems							
The Interdependence of Organisms (9-12)							
Atoms and molecules cycle among the living and non living components of the ecosystem							
Energy flows through ecosystems in one direction (photosynthesis-herbivores-carnivores-decomposers)							
Organisms both cooperate and compete in ecosystems							
The population of an ecosystem is limited by its resources							
Humans can change ecosystem balance							
Matter, Energy, and Organization in Living Systems (9-12)							
Energy for life derives mainly from the sun							
Living systems require a continuous input of energy to maintain their chemical and physical organizations							
The Behavior of Organisms (9-12)							
The interaction of organisms in an ecosystem have evolved together over time							

			Learning Activities					
Alkalinity	Fresh water macro-invertebrates	Nitrate	Water Walk	Model Watershed	Water Detective	pH Game	Practice Protocols	Model Balance
	■							
	■							
	■							
	■							